# INNOVATIVE NEW METHODS FOR MEASURING THE NATURAL DYNAMICS OF SOME STRUCTURALLY DOMINANT TROPICAL SPONGES AND OTHER SESSILE FAUNA

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Population dynamics (growth, mortality, recruitment, and reproduction) of large sessile fauna (including sponges, gorgonians, and corals), that dominate and provide structure on patches of seabed habitat in open shelf waters, 20-50m depth, is currently under study at several sites in the Great Barrier Reef region. Sites, chosen to contain representative benthos habitat fauna, are being surveyed using an ROV to document dynamics, including: mapping the large sessile fauna at each site; tagging a size range of individuals of each of several dominant species; measuring growth and mortality rates through time; observing the occurrence of new small individuals for measurements of recruitment; taking samples to confirm taxonomy and for histological examination in the laboratory to determine reproductive strategies. By tagging a full size-range of individuals of each study species, we aim to estimate lifetime growth curves in three years. From these data we will construct models of the population dynamics of sessile fauna, which can be used to estimate how fast the seabed habitat might recover in new reserve areas. This study will also document the usage of living seabed habitat by key fish species. ❐ *Porifera, sessile fauna, dynamics, growth, mortality, recruitment, ROV, video, tagging.*

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Communities of large sessile epibenthic fauna (such as sponges, gorgonians, alcyonarians and corals), provide structural complexity to the seabed - an important component of habitat for a myriad of other species - and also contribute to the biodiversity of the marine environment (Van Dolah et al., 1987; Hutchings, 1990; Pitcher, 1997). Further, they form the basis of 'bioprospecting' to discover natural products of pharmaceutical promise (Hooper et al., 1998). However, megabenthos communities are vulnerable to damage by sedimentation, dredging and extensive trawling on the seabed (Pitcher et al., 1997; Sainsbury et al., 1997). A recently completed project (Poiner et al., 1998) has demonstrated the significance of impacts of prawn trawling on tropical seabed habitats. One method of managing these impacts for ecological sustainability will be spatial closures (Sainsbury et al., 1997), e.g. establishing refuge areas to preserve representative seabed habitats. Predicting the response of megabenthos to the establishment of refuge areas, and acquiring an understanding of the ecological interactions between trawled and refuge areas, are both essential steps in the design of effective refuges for fisheries habitat and the stocks and biodiversity they support. To achieve these goals, it is first necessary to obtain information on the recovery rates of habitat and the processes that link trawled areas and refuges.

Estimation of recovery rates requires information on population dynamics, but these are virtually unknown for large sessile epibenthic fauna (Hutchings, 1990). We are investigating the fundamental population dynamics (recruitment, growth, mortality, reproduction) of structurally dominant megabenthos habitat fauna and documenting the relationship between benthic habitat and ecological usage by some commercially important finfish species.

## MATERIALS AND METHODS

STUDY AREA. Seabed areas located in the Great Barrier Reef off Townsville, Australia, were surveyed for suitable study sites in August 1997, during a voyage of the AIMS vessel RV 'Lady Basten'. Towed video cameras were used in grided surveys of four areas, each about 4,000km$^2$, in the main lagoon and among the mid-shelf reef matrix.

Four sites were chosen in an inshore area around the Palm Islands (18.7°S, 146.5°E), in depths ranging from 20-30 m. Another four sites were chosen in a mid-shelf area in the vicinity of the Slashers Reefs (18.5°S, 147.1°E), in depths ranging from 30-50 m. There is evidence that inshore areas have higher productivity of food organisms for filter feeders, than offshore areas (Adele Pile, pers. comm.) – consequently dynamics can be expected to differ between these sites. Each site was chosen to contain benthos habitat with species representative of those found on the types of seabed that are trawled for prawns or fin-fishes.

DEMOGRAPHIC MEASUREMENTS OF MEGABENTHOS. The population dynamics of sessile fauna that provide structural habitat is being documented by mapping the dominant fauna at each site; tagging several dominant species of sponges, gorgonians, and alcyonarians to identify individuals; making video measurements of individual growth and mortality rates through time; observing the occurrence of new small individuals in quadrats for measurements of recruitment; taking samples to confirm taxonomy; and histological examination in the laboratory to determine reproductive strategies.

At each site, a 4×3m quadrat was established to measure recruitment. Initially, all individuals of all species of sessile fauna within each quadrat were tagged so that the appearance of new individuals can be detected, mapped and tagged. Typically, 10-20 individuals were present and tagged in the quadrats. The settlement of any new individuals on 0.25m$^2$ concrete marker blocks placed at one corner of each quadrat will also be recorded.

To estimate lifetime growth curves in three years, we tagged across the full size-range of individuals of several species common in the area, and for the next three years we will measure tagged individuals every six months. The dominant species included sponges (*Xestospongia, Ianthella, Cymbastela, Ircinia*), gorgonians (*Ctenocella, Subergorgia, Semperina, Menella, Junceella, Muricella, Echinogorgia*) and the hard coral *Turbinaria*. We attempted to cover the size spectrum available at each site by tagging 3-5 individuals, varying in size from small to large, of each species. The absolute size range depended on the species. After tagging individuals in the recruitment quadrat, the size spectrum was completed by choosing animals within a 20-30m radius of the quadrat. Typically 35-50 individuals were tagged at each site. Large and/or old sessile fauna may grow very slowly and, in a three-year study, their growth may not be measured as precisely as small or young fauna. To counter this, benthos are being measured as accurately as possible, using laser scaling equipment and video image capture and analysis techniques (see below).

The latitude/longitude position on the seabed of each tagged individual was recorded with an underwater tracking system and differential GPS. The positions of tagged individuals were mapped so they could be found easily on subsequent

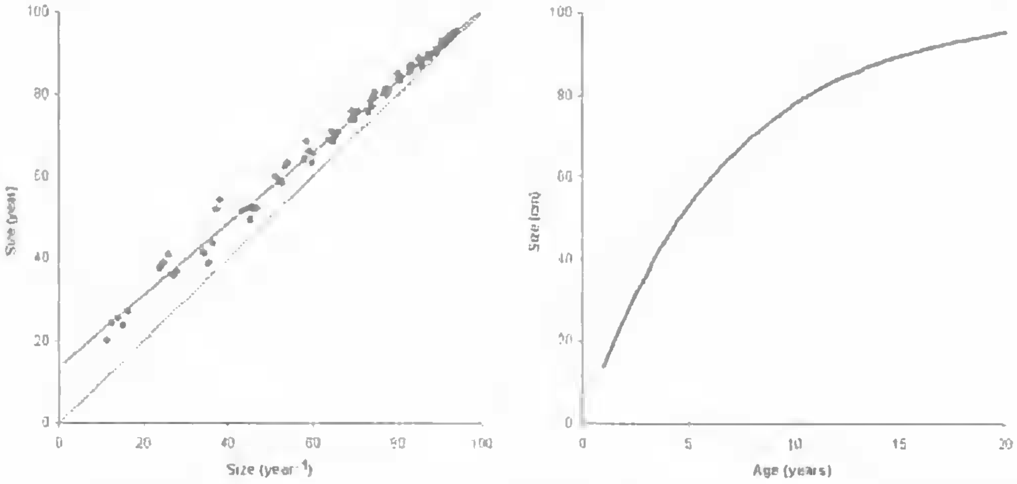


FIG. 1. A, Example of a Ford-Walford regression plot of size ($yr^{-1}$) vs. size ($yr$) to estimate the parameters growth rate $K$ (from slope=$e^{-K}$) and asymptotic size $L_\infty$ (from intersection of regression with Y=X) for a hypothetical species of sessile benthic fauna. B, The corresponding estimated von Bertalanffy growth curve for the species that may reach a size of 100cm after more than 20 years.

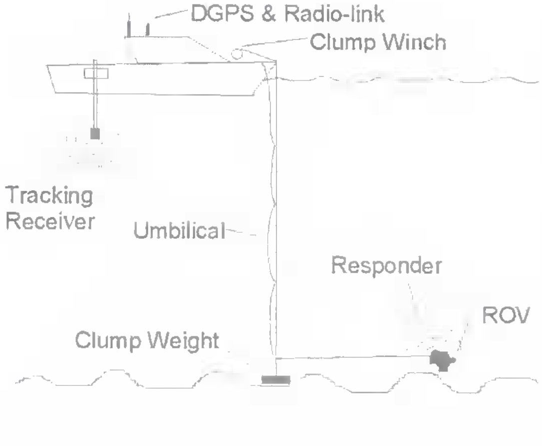


FIG. 2. Schematic diagram showing the method of anchoring a 20 m vessel over the study sites and deployment of the ROV on nylon rope.

occasions, for measurement. Growth of tagged individuals will be estimated by measuring increments in linear and/or areal dimensions seasonally. Growth curves of the von Bertalanffy form will be parameterised by statistical analysis of Ford-Walford Plots (e.g. Fig. 1; Gulland, 1983). Mortality will be estimated by the disappearance of tagged individuals. Mortality, when not directly observed from skeletal or decayed remains, can be separated from tag loss by cross-checking any apparent losses with accurate position information and the photographic record.

Every six months, separate specimens of the same suite of species are being collected for histological studies of reproductive condition. The taxonomy, identification and reproductive studies of the sessile fauna are being undertaken at the Queensland Museum. We have concentrated on relatively few species of structurally dominant fauna and, even if we cannot assign scientific names to each, we will be able to separate different species and determine which different forms belong to the same species.

LOGISTICS OF RESEARCH. Tagging in the marine environment is typically troubled by fouling and grazing by fish, which lead to difficulties with tag reading and tag loss and associated ambiguities. To minimise these problems and facilitate identification, the tags used in the study were radio-frequency identification tags in 23×4mm glass capsule form (Texas Instruments RI-TRP-RRHP), that were read automatically by an induction transceiver (Texas Instruments TIRIS Series 2000 module) mounted in an underwater housing. The tags were attached to sessile epifauna by cable-ties, or inserted into sponges with a large needle, or moulded into epoxy pucks placed at the base of the target animal.

A small remotely operated vehicle (ROV — Hydrovision 'Offshore HYBALL') is being used to conduct most of the underwater tasks. SCUBA divers assist to a maximum depth of 30 m, by setting up quadrats and tagging benthos in shallow sites. The ROV conducted these tasks on deeper sites, where it can operate for virtually unlimited periods. An acoustic underwater tracking system and differential GPS navigation enables accurate (±1m) latitude/longitude position fixing and location of tagged fauna for measurement at each sampling time. The ROV telemetry link also allows data such as tag numbers to be automatically acquired in real time, displayed, logged to database along with corresponding position, video frame numbers and captured image file-names. A pair of parallel lasers fitted in the ROV provide a 100mm scale on the video images of megabenthos for measurements. A manipulator on the ROV is used to apply tags and take samples. Deployment of the ROV involves anchoring the vessel precisely over the study sites with a 800kg weight as an anchor on a 25mm plaited nylon rope that can absorb up to 30% rise and fall of the vessel on the waves (Fig. 2). The ROV umbilical is clipped onto the rope to minimize the drag due to currents. This method is simple and effectively enables repeated, accurate positioning of the vessel over the study sites.

Integrated data acquisition, storage and retrieval are central to the logistics of the field operations and analysis. Custom software controls this integration of data for vessel position and orientation, ROV tracking, video frame, and tag numbers (Fig. 3). It also provides a navigation system that gives accurate coordinate positions of the vehicle, which are overlaid on the video tape record and displayed as an ROV track on a plotter window. The positions of tagged fauna are shown as way-points to facilitate their location (Fig. 4). When a tagged animal is detected, previous images of that subject are displayed for confirmation and to enable the same image orientation and perspective to be captured.

The laser scaled images of fauna recorded from the ROV's video camera are captured live or from tape. The lasers are calibrated by projecting onto scaled grids to check accuracy and precision of measurements of size through time. Image analyses are achieved efficiently by using a custom software application to control, link and synchronise the field

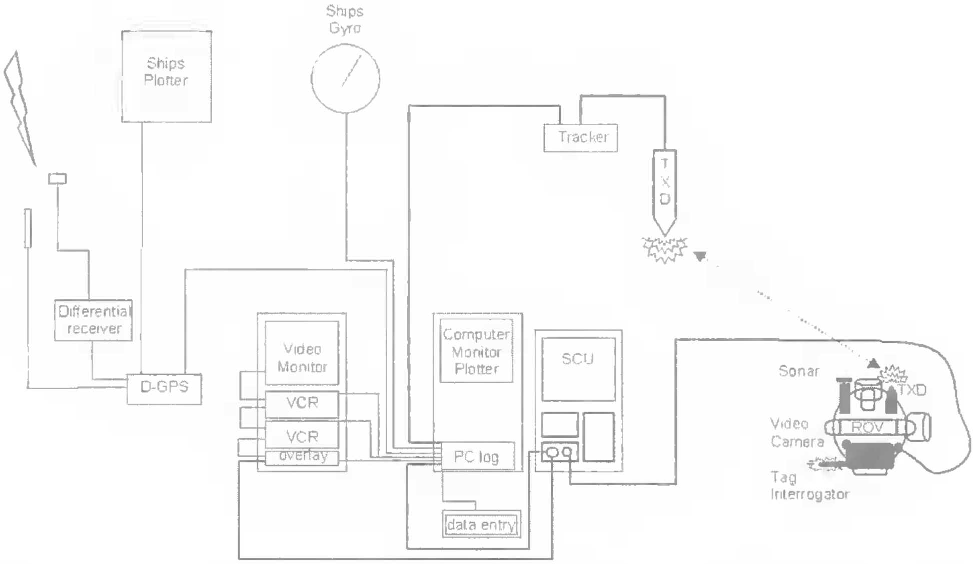
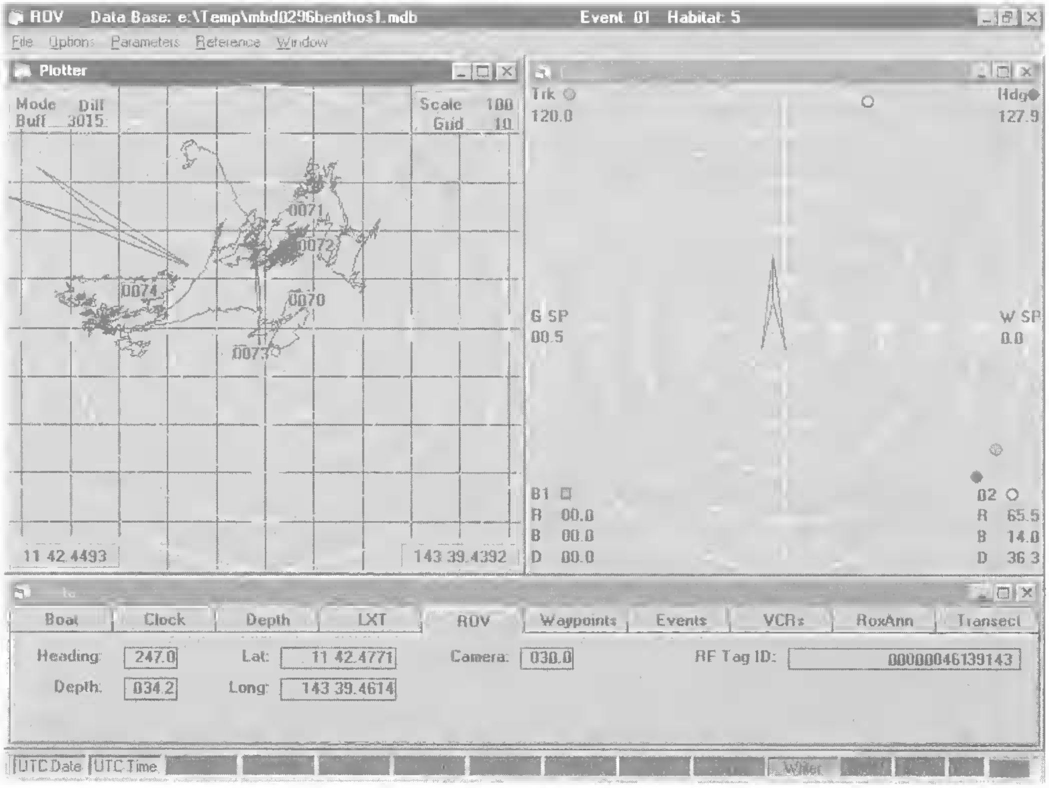


FIG. 3. System diagram showing integration of components necessary for automated tracking of the ROV and synchronous logging of position, tracking, tag numbers and video data, to facilitate post-analysis and measurement of sessile benthic fauna. DGPS: differential global positioning system, VCR: video recorder, PC: logging computer, SCU: surface control unit for ROV, TXD: tracking system transducers.


ROV Data Base: e:\Temp\mbd0296benthos1.mdb Event: 01 Habitat: 5

Mode Diff
Buff 3015
Scale 100
Grid 10
11 42.4493
143 39.4392

Trk 120.0
Hdg 127.9
G SP 00.5
W SP 0.0
B1
R 00.0
B 00.0
D 00.0
02
R 65.5
B 14.0
D 36 3

Heading: 247.0
Depth: 034.2
Lat: 11 42.4771
Long: 143 39.4614
Camera: 030.0
RF Tag ID: 00000046139143

FIG. 4. User interface of the custom acquisition, tracking and logging software, showing vessel-relative ROV tracker (right window) and ROV navigation plotter (left window) with waypoints (e.g. 0070 to 0074), ROV track (irregular black line), vessel position (arrowhead), ROV position (pale circle off starboard bow near 0073). The lower window shows data acquired and status.

databases (of tracking, positioning, and tag numbers) with the video images and execute macros on the Optimas® image analysis software. An operator digitises the lines for the laser points (100 mm scale), height, width, and area of profile as appropriate for the growth form (Fig. 5) and chooses species and condition information from a select list. The software transfers the measurement data to a database along with the image filename and corresponding field data. This provides a semi-automated method for extracting the required quantitative data in the form of date/time, site, tag-number, species, position, morphometrics and condition.

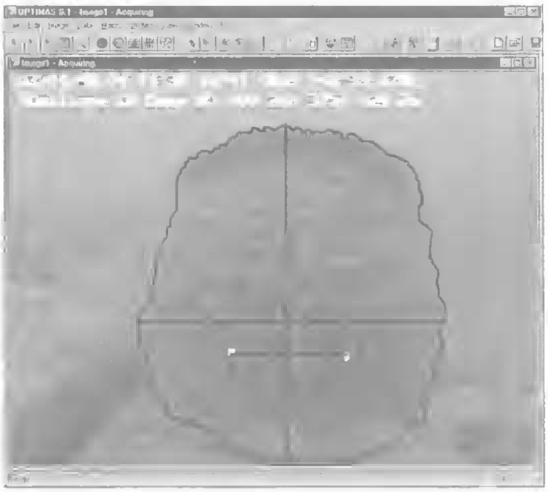


FIG. 5. Captured image of a computer screen showing results of the macro run on Optimas by the custom control software, to measure benthic fauna – *Xestospongia testudinaria* in this example. The tag interrogator antenna is visible in the lower left of the image.

## RESULTS

The first tagging fieldwork was conducted in March 1998. Eleven of the most abundant species were targeted for tagging and a total of 174 sessile fauna were successfully tagged, including 26 putative species. The available size-spectrum of each species was successfully covered in most cases (Table 1). Specimens of these species were collected for taxonomic confirmation.

The second tagging field trip is currently underway (December 1998). In the four study sites around the Palm Islands, 95% of tagged individuals have been re-measured, 9 individuals were not re-located, 5 incidences of mortality were confirmed, and 13 new recruits were observed in the quadrats.

To date, results have demonstrated that the logistics of the project are working as planned. Tagged individuals can be re-located successfully, tags can be re-interrogated and cross-referenced in the database, captured images can be measured with mm accuracy, recruitment can be observed and mortalities confirmed. The methodological protocols that have been established for ROV deployment and for benthos measurement will be used for future repeated visits to individual tagged fauna to provide a consistent series of measurements.

TABLE 1. List of species targeted for tagging during fieldwork in March 1998, with statistics of each species for height (cm) of tagged specimens, count of numbers tagged by size-categories in classes of one standard deviation (sd) unit relative to the mean, and total count.

| Species | Min Height | Mean Height | Max Height | Small <-1 sd | Med-small -1<sd>0 | Med-large 0<sd>1 | Large >1 sd | Total Count |
|---|---|---|---|---|---|---|---|---|
| *Ctenocella pectinata* | 10.6 | 34.1 | 69.9 | 4 | 6 | 8 | 4 | 22 |
| *Xestospongia testudinaria* | 9.8 | 23.2 | 42.1 | 3 | 5 | 6 | 4 | 18 |
| *Menella* | 5.0 | 18.0 | 28.9 | 2 | 3 | 10 | 1 | 16 |
| *Cymbastela concentrica* | 9.4 | 21.6 | 43.5 | 3 | 4 | 4 | 2 | 13 |
| *Subergorgia reticulata* | 14.6 | 43.9 | 108.1 | 2 | 4 | 4 | 3 | 13 |
| *Turbinaria* | 2.0 | 24.4 | 62.0 | 1 | 5 | 6 | 1 | 13 |
| *Semperina brunei* | 10.0 | 34.6 | 53.3 | 1 | 4 | 7 | 1 | 13 |
| *Ianthella basta* | 16.8 | 31.0 | 46.7 | 4 | 1 | 4 | 2 | 11 |
| *Junceella divergens* | 9.0 | 27.5 | 41.2 | 2 | 2 | 7 | 0 | 11 |
| *Muricella* | 13.1 | 25.9 | 40.7 | 1 | 4 | 4 | 2 | 11 |
| *Echinogorgia* | 20.4 | 33.6 | 45.8 | 1 | 2 | 2 | 1 | 6 |
| Others | | | | | | | | 27 |

## DISCUSSION

Our study has developed techniques for *in situ* investigations of the types of large sessile fauna that provide structural habitat in deeper areas, where access by divers is limited or impossible using conventional breathing equipment. These methods open the opportunity for understanding the poorly known ecology of these faunas, and will lead to greater appreciation of their role and importance. The study will also document usage of living habitat by key fin-fish species, in terms of species micro-distribution, shelter requirements, and food chain links.

The growth, mortality and recruitment rates estimated by this study will be used for developing population dynamics models of the large sessile fauna. The structure of these models will be of a size-based matrix form (e.g. Hughes, 1984). Basically, for each species, the models will have several size categories, the number of which will depend on life history characteristics; recruitment to the smallest size-category will be the probability of settlement of larvae; each larger category will receive recruitment due to growth from lower categories; and individuals within each size category will have a probability of dying or growing to the next size category (the possibility of negative growth will also be included if required. Other factors to be included in the models include the possible effects of density of the same and other benthos taxa, and the reproductive potential and proximity of source populations on supply of larvae.

Results of this study can be used to examine a number of issues, including: the establishment of refuge areas on the seabed, trawling strategies, habitat restoration, stakeholder conflicts, and conservation. These issues revolve around the impact of trawling on seabed habitat and associated stocks, and the rate of recovery of habitat if areas were reserved. In particular, models will contribute to the development of management strategies to improve the environmental sustainability of trawling, by simulating the interaction of the dynamics of habitat fauna with the dynamics of trawl impacts and estimating levels of trawl effort that do not cause continuing degradation.

Information of this kind will become increasingly important as the requirement for ecologically sustainable fisheries management is implemented in trawl fisheries from the temperate zone to the tropics. The lessons learned from this study in the form of knowledge of habitat dynamics, and methods for monitoring habitats and the commercial stocks they support, will contribute to a rational balance between ecologically sustainable fishing and biodiversity conservation when ESD related management objectives are implemented in those Australian fisheries dependent on seabed habitat.

## ACKNOWLEDGEMENTS

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